

## CONCLUSIONS

1. For very bad soil and drainage conditions, or where past evidence indicates frost heave, 3- or 4-inch porous sub-bases of slag or crushed stone will greatly improve the condition. These bases must always be carefully drained.

2. The length of slab or the distance between transverse joints is very important. The results of the crack surveys on these projects indicate that transverse joints should be spaced every 30 feet, certainly not to exceed 35 feet apart.

3. Clean sand is so mobile under pressure that its use as a porous subbase is impracticable. A half-and-half mixture of sand with the subbase soil for a depth of 3 or 4 inches may work out more satisfactorily.

4. Cement admixtures with the subbase soil within the economic range of its use have not proved of any value.

5. The use of any admixtures with heavy clay soils during wet seasons is almost impossible because of the cohesiveness of the clay. It should be discouraged.

6. Cinders as a porous subbase for concrete proved worse than useless. There is also danger from their use—for in wet seasons the sulphur in them may damage the concrete.

7. The results from using different depths of porous sub-bases seemed to indicate that depth of material beyond 3 or 4 inches is not important.

8. From the last column in Table No. 8, it may be seen that but six different sections out of 30 failed to show better results than were shown by the untreated sections in the same project.

9. Summing up the results from the use of each of the different materials used in these experimental tests, it is seen in Table No. 9 that all but three—gravel, sand, and the cement-clay admixtures—gave better results than were secured from the untreated sections.

## RESURFACING STREETS AND HIGHWAYS

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Did you ever look at the rug in your living room and think, "That rug is about worn out—we'd better get another"? Then, after due cogitation, comparison of different makes and designs, thoughts about colors, and guesses at the probable life, you buy a rug. Do you tear up the floor and put down a new one? You do not. You may polish the old floor and wax it, but you put the rug down and know that the floor itself will never wear out, because the rug will take all the wear. And

when the second rug is worn out, you can continue indefinitely (so long as the money lasts) to re-cover your floor as it needs it. In the kitchen, you have some linoleum. After a time the surface wears off so that the design isn't pretty, and the neighbors think your wife ought to have a better-looking floor in the room where she spends so much time for your benefit. Instead of taking it up, you buy a new one and put it down over the old. A more resilient floor is produced, and your wife doesn't have a lame back from making pies.

Well, that is what we do on the road, too. If we have good sense, we do not tear up the old pavement but use it as we did the living room floor to put a new covering on. We do not tear up our secondary roads when they begin to show signs of failure, but we re-cover them and produce thicker, more resilient, and better roads.

Maybe our rug was not nearly so bad as we thought it was, and it needed only cleaning and patching. If it was an expensive rug, we probably decided to let the rug man from the cleaning establishment look it over and give us his advice. If it was a cheap rug, we thought that the cleaning and the patching would cost more than a new one, and so we let it go at that. We seldom junk our oriental rugs just because they show signs of wear. No! We maintain them and keep them in service until their economic life is ended.

#### IMPORTANCE OF ADEQUATE MAINTENANCE

And similarly with our pavements. We have been on a jamboree of road building for the past twenty years. We have on hand miles and miles of expensive highways that are like our expensive rugs. They are too costly to throw away, and yet they are not adequate for modern traffic conditions. They have not been suitably maintained. If we had given our undivided attention to taking care of what we have, we should all of us be in better condition today.

A year or so after the Dawes Plan was instituted in Germany, that country announced to the world that, because of excessive payments necessary to her former enemies, her enormous investment in railways was being jeopardized. She had no money for maintenance of track or rolling stock, and she predicted that unless she were allowed to maintain these there would be deplorable loss of life, as well as staggering commercial losses. The recent money conditions in our own country are bringing about, in a measure, a similar condition in our railroads. Neither cash nor credit has been available for the railroads to keep up their properties, and, as a consequence, we find them far from the splendid physical condition in which we have hitherto always found them.

Some of the railroads' troubles have been due to building parallel competing lines where one line would have been adequate. We see now a desire on their part to combine and

operate over a single system, junking the parallel route that does not pay. Ten or twelve years ago, there was an overpromotion of highway construction. And, today, we see, on the part of some, a desire to forget these costly roads in order to concentrate on super-highways. These latter may be said to be like the newly desired combined railroad systems.

But we must not forget what we already have. We must maintain and use these miles of pavements. Twenty years ago I went about our country preaching to our highway engineers the gospel of "Save what you have." And I am still at it. Maintenance! Adequate, painstaking, thorough, year-round maintenance is what we need. We must keep our methods up to date, and after we have maintained our roads they should be in condition to take the present-day motor traffic as satisfactorily as a brand new pavement.

As you immediately sense, this means that maintenance, as I think of the term, is not simply filling up the holes that develop in all types of pavements. It is much more than this. It may mean the entire resurfacing of the old pavement. It certainly means the smoothing up of existing roads for high-speed traffic. It means the incorporation of safety measures where necessary. It means what it has meant on railroads, namely, the preservation of the old and the installation of the new to produce a perfect whole.

And the millions that we have put into our highways in the past demand just that. There is no reason why we should junk what we have simply because we have been too unseeing to keep abreast of the times. If we have dropped behind in the race, let us step on it, and, by dint of skilled maneuvering, keep up with the best.

#### WHAT ARE WE RESURFACING?

Now let us get back to our rug again. If we look under the rug, we may find all sorts and conditions of floors. I remember seeing once upon a time a new house which apparently was finished with hardwood floors throughout. But, when the rugs were removed, it was found that the carpenter had laid hardwood only where it would show, and that under the rugs was yellow pine. It seems to me that I faintly remember having seen bases for pavements built in similar fashion. How often do we find a concrete foundation that has failed because the contractor put more faith than cement in it? Now, if the floor in the house is rough and uneven, the rug is going to suffer, and it will show worn places which soon will become holes; and if the base of a pavement is worthless, then there is no use covering it with the expectation of salvaging it, for the new top will go the way of the rug.

I have used the analogy of the rug to the pavement to bring home to you the simple facts of construction and maintenance which people so frequently lose sight of when they

think in terms of highways. That same taxpayer who knows that he has to paint his house and reshingle it from time to time is the same one that thinks a pavement should last forever because it was paid for out of public funds.

The subject of this talk merits a good-sized book to do it justice. There are so many miles of roadway that need resurfacing, there are so many types of pavement in those miles, there are so many climatic conditions to be met, there are so many traffic problems to be solved, and there are so many interests involved, that I can do no more than generalize on much of the work in the time allotted.

With funds available from the CWA, the cities are interested in improving their pavements right now. But if we inquire of the city engineer here and there, we find that he just does not know what to do. Some would like to tear out the old pavements and rebuild. Others would merely like to repair what they have, while others would like to re-cover those pavements that are not in good condition. The question immediately arises as to how much money is available for materials and how much for labor. This may be the deciding factor. If you are restricted to 12.5 per cent of the total funds for materials, you can do little more than repair work. If you can get an additional equal sum from your city, you probably can do a fair share of resurfacing.

Let us look into the question of what the old pavements are like. What do we find to be resurfaced? Gravel, macadam (so-called, though most of it would make Mr. McAdam blush to think his name was coupled with such shoddy work), bituminous macadam, retread, bituminous concrete, sheet asphalt, cold mixes gone bad, brick, and concrete. All of these are to be found in Indiana. Can we satisfactorily resurface each particular type? Yes, if we go about the work carefully, thoughtfully, earnestly, and honestly. What shall we use? We *can* use any type to resurface any other type, but such a procedure might well be as foolish as putting a new oriental rug over the kitchen linoleum. Thus, it would be absurd to lay a sheet asphalt top over an old gravel road. Someone may say, "Well, it has been done," and no doubt it has, but that does not mean that it was a sane thing to do.

#### USE OF RETREAD

Let us start with our cheaper types, that is, the gravel and the broken stone. About a dozen years ago, when I was consulting engineer for a tar company, I introduced and developed what is now well known as the retread type of resurfacing. You have many miles of retread in this state. As its fond parent, I am, naturally, rather proud of its record. Some changes in materials and its construction have been gradually creeping in, but essentially it is the same as I started

with. The mixed-in-place or retread idea was apparently wrong in theory, but in practice it works well. The original jobs were all mixed with tar, but asphalt is also used now. The tendency at the moment is to use heavier grades of bitumen than formerly. In the summer time, this is possible if you are well organized and have sufficient forces and machinery to do the work quickly. The ordinary variety of highway official who starts out to do retread work for the first time had better keep to the less viscous materials, or he may find himself in serious trouble.

During 1933, New York State has been doing these jobs with but one mixing. All of the stone is placed on one side of the road, where it is "shot" with about 8/10 of a gallon of tar per square yard of surface. The tarred stone is then spread out over the entire roadway and is turned once or twice. The road is rolled, and the surface voids are filled with  $\frac{1}{8}$ - to  $\frac{1}{4}$ -inch stone chips. A seal coat of tar at  $\frac{1}{4}$  gallon per square yard is applied, covered, and rolled, and then a second seal and cover is applied and rolled. The thought is that this method will seal the surface against water and provide a top that will last longer without surface treatments.

If a gravel road or a macadam is to be retreaded, I always advise that after the holes have been filled, the bumps taken off, and the old surface made reasonably smooth, it be given a surface treatment of about  $\frac{1}{8}$  gallon per square yard of a light bitumen. This will keep the dust from mixing with the new material and will also be of service if rain should fall before the new top is put on. Of course, if you are going to retread an old asphaltic concrete, brick, or concrete pavement, you should make sure that the old surface is in condition to receive the new one. Waves, holes, bad cracks, and disintegrated places will eventually show up in the new top unless they are patched before the resurfacing begins.

Right here I want to call your attention forcefully to the fact that these retreads, mixed-in-place tops, or other similar jobs are cheap surfaces for light to medium traffic. They never were meant to carry heavy through traffic, and in the majority of cases, they just won't do it. Every once in a while some misguided individual puts such a topping on Main Street and wonders why it goes to pieces long before he thought it should. Of course, there have been some miracle jobs with retread that have stood up wonderfully well under really heavy traffic, and their makers boast about them. But, on the whole, they are meant for secondary roads, and in such locations they give excellent service for little money. Of course, there are many miles of mixed-in-place jobs right now that should be resurfaced by using the same method. In this way you build up a well-bound road surface, reasonably thick, that may some day be almost a real pavement.

## PENETRATION MACADAM

So much for this type of top. There are many others that can be used for the old gravel and macadam roads either in city or country. The penetration bituminous macadam is next on the list. It is inexpensive, and, properly laid and maintained, it gives a good account of itself. Notice, however, that I specifically said PROPERLY laid. I believe that penetration roads have often earned a bad name because of the carelessness of construction rather than any other one thing. There has been too much taken for granted, and too little study on the part of the builders. Slipshod methods have produced miserable results. We are now seeing the promotion of penetration cement macadam but if its promoters do not insist on careful attention to details of construction, the method will be condemned almost before it gets under way. It is a reversion to the old Hassam pavement, which is a most excellent one if only care is used, but a quick and expensive failure otherwise.

So, whether you use asphalt, tar, or cement for the binder in your penetration macadam, see to it that no chances are taken in construction methods. If you do not know how to go about it, do not be ashamed of your ignorance—there are millions like you—but get a representative of the company that sold you the binder to stick with you until you do. There are many books on the market that explain it all, and there are numerous excellent pamphlets put out by the materials company that go into more detail than most of the text books. Get these and study them carefully and thoroughly before you begin to spend money. If you will do this, you will really be able to build a good penetration macadam that will last for years and years with little upkeep. I haven't time to go into the details of construction here, nor to explain the asphalts, asphaltic emulsions, or tars that may be used. But I can assure you that the penetration macadam has not the high name it should have, and that the fault is not the pavement's.

Gravel streets in towns may be resurfaced with higher types than these I have been explaining, provided the gravel is well consolidated and at least ten inches thick. Such a gravel makes a substantial base for asphaltic concrete, brick, or concrete tops. But it must be remembered that in towns, and perhaps in villages, too, you must make allowance for raising manhole covers, catch basins, inlets, utilities box covers, and so on. Resurfacing with these expensive materials is not a haphazard affair, and your estimates must include all of the extras I have mentioned, as well as others that may come into the local picture. You must ever keep in mind that if you are going to resurface a gravel or a macadam street with asphaltic concrete the new top must not be of less thickness than two inches, and preferably more than that. Brick will require at

least three and three-quarter inches, and concrete at least five inches. Hence, look to your curbs and gutters, street intersections, and manholes.

Many of the old gravels and macadams are highly crowned. In this day of high speed, we do not like that. Under the provisions of P.W.A. and C.W.A., it should be a simple matter to remove these objectionable crowns with hand labor. In fact, much of the cost of the new top can be charged off to this kind of work, and indeed must be so charged if the labor costs and materials costs are to balance properly. Of course, if the old crown is removed, the flattened roadbed may then be too thin at the center. This should be carefully ascertained by digging through to the subgrade in several places. It will not do to resurface an old gravel road from which you have removed most of the gravel.

#### WINTER WORK

The question has arisen, especially in the C.W.A. work in Chicago, as to the most suitable type of resurfacing for winter months. As a matter of fact, there is no type that is good to lay in extremely cold weather unless it be some form of block pavement such as brick, stone block, or asphalt block, and even these might not prove to be satisfactory if the filler for the joints is to be a bitumen or cement grout, since the former would chill so quickly as to fail to enter the joints, and the grout would freeze before it set.

It is possible to lay two types of bituminous pavement in rather cold weather. Asphaltic concrete may be laid provided it reaches the job promptly from the mixing plant and is spread and rolled rapidly. However, if irregularities develop during the laying, it will be next to impossible to roll these out before the mixture has chilled so much as to be unmanageable. The other type is a cold mix made with a cut-back tar. Here I suggest that the solvent be increased enough to reduce the viscosity considerably below that normally used for summer work. One trouble with this cold mix is the procuring of dry stone, which may be more or less difficult in winter weather. These cold coal-tar mixes may often be used where the asphaltic cut-back mixes are not workable. Care must be taken with them to insure a seal coat early in the spring to seal the surface, and repairs must be made during the winter as often as may be necessary. And that may be often if your workmen are unfamiliar with the work, as most of these C.W.A. men are.

I strongly suggest that even under the present economic strain no work be done with actual paving when the temperature is less than 32° F. Put your workers on something else until the weather moderates.

In the Chicago area, paving has been going on since the first of December. The work consists of resurfacing about

600 miles of old macadam and bituminous macadam with asphaltic concrete. These old macadams vary in thickness from six to fifteen inches, and their cross sections are those of the "gay 90's."

If gravels or macadams are to be resurfaced with brick, there should be some brain work done before starting operations. Most certainly the old high crowns must be eliminated. Now your old timer will say that this is easy—just do it with a sand cushion. And I say that anyone who does that should be jailed for life. The sand cushion has been the ruination of more brick pavements than anything else. It would be possible, of course, to make a slush coat of sand, cement, and water, as Illinois does for this work when resurfacing with brick over worn concrete, and strike it off, let it set, lay a mastic cushion on it, and then lay the bricks. Carefully done, I think that would be the best scheme, but perhaps a cheaper and nearly as good result would be obtained if the old surface is scarified along the center to remove the crown. Then roll well, building up the sides where necessary with what you take off the center. On this new surface spread a mastic cushion made with sharp sand and a suitable bitumen. This cushion should not be more than two inches thick as a maximum, and not over one inch on the average. My laboratory experience, dating from tests made in 1914 and my field work in the past three years, shows conclusively that this mastic cushion should be made with 93% sand and 7% bitumen by weight. The bricks are laid directly on the cushion and rolled, and the joints are filled with suitable filler.

Of course, the old road can be resurfaced with a regular concrete pavement, in which event an excellent result should be attained, since the concrete would have a fine, substantial base under it. If the old macadam is highly crowned, then the pavement laid thereon will have a naturally thickened edge. Two such pavements that I have watched have proved to be highly satisfactory.

So far, I have talked solely about resurfacing old gravel and macadam roads. There are many other types that may require resurfacing. What shall we do with a bituminous macadam or bituminous concrete that needs resurfacing? First of all, carefully repair the old top, making the patches level with the rest of the pavement. Bumps or depressions will show up later if you resurface with any bituminous type. Now resurface with any method you like. But, if you use a bituminous top, do not skimp on thickness. I do not care what any salesman for any material tells you about being able to get a good job with his material laid one inch thick. It just isn't so. A thin bituminous resurfacing is about as lacking in substance as a thin pie. Neither one will give you satisfaction. If the job is in town and you lay a two inch resurfacing, you may find that the gutters are not deep enough.



You may skimp a little in thickness along the edges, say for a foot and half back from the curb, and so get sufficient depth to carry off the water. You may lay brick, or asphalt block over the old pavement with good results. Or, again, you may obtain excellent results with concrete.

#### RESURFACING SHEET ASPHALT

Frequently we find sheet asphalt that has gone bad for sundry reasons, and we wonder what to resurface with, especially in those localities where there is no asphalt plant now in existence. Usually the sheet was laid on a concrete base, and if you tear it up, you find that the concrete is badly shattered or cracked. What to do?

Of course the base must be repaired before anything else is attempted. The pavement may be resurfaced with any one of a half dozen materials. For instance, a cold plant mix of aggregate and asphalt, or coal tar and aggregate, is easy to lay and will give a good account of itself. If either of these is used, the holes in the old pavement must be mended before the new top is laid. Another material is asphalt block, provided there is a plant near by so that freight rates are not too high. Rock asphalt has been used to advantage in such work, and in Indiana the freight rates would not be excessive. Paving brick is suitable, and if the old pavement is well patched before the bricks are laid, you should get a job that will last for generations. There is no good reason why concrete resurfacing should not be satisfactory provided the thickness of the concrete does not interfere with intersections, curbs, and inlets. E. M. Fleming of the P. C. A. says that "Over flexible or badly broken base pavements, a thickness of five inches is desirable. Resurfacing thinner than four inches is only satisfactory for strictly residential streets carrying vehicles of light weight, or where the base pavement is new and unbroken." Of course, on rural highways five inches would mean nothing, but in town considerable care and ingenuity would have to be exercised to avoid unpleasant dips at street intersections, and the cost of resetting curbs, man-holes, and inlets must be counted.

Sometimes these old sheet pavements were not laid on concrete, but rather on old stone block, brick, or anything that was handy. They may have been, and probably were, resurfacing jobs originally. The resurfacing of a poor pavement is something I shall not attempt to describe here, other than to say that a good scarifier and power shovel are the best implements to use.

Of course, if there is a mixing plant at hand, the most sensible way to resurface a sheet asphalt pavement is with sheet asphalt. Occasionally, it is possible to obtain a semi-portable plant if there is no permanent plant at hand.

### RESURFACING BRICK

Brick pavements may be surfaced by any of the preceding methods. In addition, another scheme that sometimes works well is to remove and clean the bricks. Repair the foundation, lay a mastic cushion over it, and then re-lay the bricks bottom side up. There will be a loss of from 15% to 30% of the old bricks, and these should be replaced with others of similar size and color. The new bricks should be laid in their own area, as it is not good practice to mix the old with the new.

I have seen some very good examples of concrete over old brick, and I have seen some that are not so good. The latter are generally due to too thin a resurfacing and to defects in the old pavement that were not attended to. There is an example at Urbana, Illinois, that is interesting because the concrete was laid over a worn brick pavement, and I am told that the concrete varies in thickness from about two and a half inches to nearly seven.

One item that is worthy of note is that, where the resurfacing is thin, there was evidently some difficulty experienced in keeping the reinforcement at the same level, with the result that it sticks through the surface and in some places has had to be cut off, as it was poking holes through tires.

There seems to be a diversity of opinion among engineers as to the propriety of laying concrete directly over the old brick. Some hold that a cushion of a sort should separate them. I have seen jobs where the brick was given a surface treatment with tar, and the new concrete laid thereon. I have seen others where the brick were simply well cleaned, sprinkled with water, and the concrete laid. I have found no difference in the resulting pavements. Therefore, I have no answer to this.

### RESURFACING CONCRETE

A worn concrete pavement usually makes an excellent foundation for all types of resurfacing. Any of the preceding methods may be used, if certain details are attended to. If brick is to be laid over old concrete, then it is highly desirable to widen the base by the addition of concrete curbs against which the brick may be laid. Of course, this is not necessary if the bricks are grouted. Such a curb is advisable for bituminous types.

Concrete over concrete is popular. Here again it will not do to skimp the job. If you feel able to spend the money necessary to lay a concrete pavement, why jeopardize the result by making the new top too thin? In general, it has been found satisfactory to lay it five inches thick. There have been a few three-and-a-half to four-inch tops that have given good results, and there have been many more that have not. If you are going to do the work, do it thoroughly and well. Put on

five inches of concrete and reinforce it with small steel members closely spaced. I believe in the use of transverse joints at less than 30 foot intervals. These should be carefully dowelled. I also believe that a center joint is necessary, with adequate design for the transfer of load across the joint. While these joints add to the initial cost, they reduce the maintenance and repair bills. Therefore, it will be well to use them.

It is not the purpose of the paper to talk of details of construction, and I shall leave you here with the new rug on the old floor, and with the bills for it hanging over your heads.

## WIDENING AND REPAVING OR RESURFACING STATE HIGHWAY ROUTES THROUGH CITIES

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In the conception of the law creating a state highway commission, we had in mind expediting travel between centers of population, such as county seats and neighboring cities of the larger class. We wanted to go, for instance, from Logansport to Delphi. We did not see that in these short fifteen years our highway system would become the main transportation system of Indiana, and, linked up with similar roads in other states, would provide the principal transportation system of the nation.

A few years ago when we in Lake County wanted to come to Indianapolis, we boarded a train to make the trip. Of late, however, we think only of driving, and after riding along over smooth pavement for miles and miles, we wonder why we should bump through Lebanon. The original law did not permit the state highway commission to make improvements in cities of over 2,500 population. Later this was raised to 3,500. Last year, when the law was again rewritten and enacted, it was considered making it possible to go through all cities on state highway routes, but because the special session of the 1932 legislature had taken half of the money from the highway commission, it was felt that the commission should not take over additional mileage with this handicap. So, as far as the statute of the state is concerned, the commission is unable to make improvements in cities of over 3,500 population.

With the enactment of the National Reconstruction Act, \$400,000,000 was set aside and given to the Bureau of Public Roads to be spent by the state highway commissions, as its agents, under the following regulations: At least 25% had to be spent on the federal system of highway routes outside of the cities. At least 25% had to be spent on the routes of state highways through the cities and on the federal system.